

IGR J16194–2810: a new symbiotic X–ray binary[★]

N. Masetti¹, R. Landi¹, M.L. Pretorius², V. Sguera², A.J. Bird², M. Perri³, P.A. Charles⁴, J.A. Kennea⁵,
A. Malizia¹ and P. Ubertini⁶

¹ INAF - Istituto di Astrofisica Spaziale e Fisica Cosmica di Bologna, via Gobetti 101, I-40129 Bologna, Italy

² School of Physics & Astronomy, University of Southampton, Southampton, Hampshire, SO17 1BJ, United Kingdom

³ ASI Science Data Center, via Galileo Galilei, I-00044 Frascati, Italy

⁴ South African Astronomical Observatory, P.O. Box 9, Observatory 7935, South Africa

⁵ Pennsylvania State University, 525 Davey Laboratory, University Park, PA 16802, USA

⁶ INAF – Istituto di Astrofisica Spaziale e Fisica Cosmica di Roma, Via Fosso del Cavaliere 100, I-00133 Roma, Italy

Received 19 March 2007; Accepted 24 April 2007

Abstract. We here report on the multiwavelength study which led us to the identification of X–ray source IGR J16194–2810 as a new Symbiotic X–ray Binary (SyXB), that is, a rare type of Low Mass X–ray Binary (LMXB) composed of a M-type giant and a compact object. Using the accurate X–ray position allowed by *Swift*/XRT data, we pinpointed the optical counterpart, a M2 III star. Besides, the combined use of the spectral information afforded by XRT and *INTEGRAL*/IBIS shows that the 0.5–200 keV spectrum of this source can be described with an absorbed Comptonization model, usually found in LMXBs and, in particular, in SyXBs. No long-term (days to months) periodicities are detected in the IBIS data. The time coverage afforded by XRT reveals shot-noise variability typical of accreting Galactic X–ray sources, but is not good enough to explore the presence of X–ray short-term (seconds to hours) oscillations in detail. By using the above information, we infer important parameters for this source such as its distance (~ 3.7 kpc) and X–ray luminosity ($\sim 1.4 \times 10^{35}$ erg s^{−1} in the 0.5–200 keV band), and we give a description for this system (typical of SyXBs) in which a compact object (possibly a neutron star) accretes from the wind of its M-type giant companion. We also draw some comparisons between IGR J16194–2810 and other sources belonging to this subclass, finding that this object resembles SyXBs 4U 1700+24 and 4U 1954+31.

Key words. Astrometry — Stars: binaries: general — X-rays: binaries — Stars: neutron — Stars: individuals: IGR J16194–2810

1. Introduction

Low-mass X–ray Binaries (LMXBs) are interacting systems composed of an accreting compact object and a low-mass ($1 M_{\odot}$ or less) main-sequence or slightly evolved late-type star. Recently, a small but growing subclass of LMXBs is gaining more attention. The systems belonging to this subclass have a M-type giant, rather than a dwarf, as mass donor. By analogy with symbiotic stars, in which a white dwarf accretes from the wind of a M-type

giant companion, they are called symbiotic X–ray binaries (SyXBs; Masetti et al. 2006a).

SyXBs are extremely rare: up to now, among more than 150 LMXBs known in the Galaxy (Liu et al. 2001), only 4 firm SyXB cases are known: GX 1+4 (Davidsen et al. 1977; Chakrabarty & Roche 1997), 4U 1700+24 (Garcia et al. 1983; Masetti et al. 2002), 4U 1954+31 (Masetti et al. 2006a,b; Mattana et al. 2006) and Sct X-1 (Kaplan et al. 2007). All of these objects but GX 1+4 are characterized by X–ray emission ranging between $\sim 10^{32}$ and $\sim 10^{34}$ erg s^{−1}, and by the absence of the features typical of accreting systems in their optical spectrum (e.g., Masetti et al. 2002, 2006a); GX 1+4 shows instead a more intense X–ray luminosity (around 10^{36} – 10^{37} erg s^{−1}) along with a composite optical spectrum with strong emission lines (e.g., Chakrabarty & Roche 1997). All sources show long- and short-term X–ray variability.

Send offprint requests to: N. Masetti, masetti@iasfbo.inaf.it

[★] Partly based on X–ray observations with *INTEGRAL*, an ESA project with instruments and science data centre funded by ESA member states (especially the PI countries: Denmark, France, Germany, Italy, Switzerland, Spain), Czech Republic and Poland, and with the participation of Russia and the USA, and on optical observations collected at SAAO, South Africa.

This difference in the optical spectra is due to the fact that the luminosity of a M-type giant is $\sim 10^{36}$ erg s $^{-1}$ (most of which is emitted in the optical and near-infrared ranges), thus only in case of large X–ray luminosities can spectral features produced by accretion emerge in the optical spectrum. It is thought that this difference stems from the mass accretion rate and therefore from the evolution of the system, GX 1+4 being likely tighter and more evolved according to Gaudenzi & Polcaro (1999).

All of these systems are suspected to host a neutron star (NS). However, only for sources GX 1+4 and Sct X-1, and possibly for 4U 1954+31, is the nature of the accretor known: their X–ray emission is pulsed, indicating that the accreting object is indeed a NS (Lewin et al. 1971; Koyama et al. 1991; Corbet et al. 2006, 2007). The system 4U 1700+24 only displays random X–ray variability: however, this is more likely due to geometric effects rather than to a different type of accretor (Masetti et al. 2002).

Here we present the discovery of the fifth member of the SyXB subclass: source IGR J16194–2810. This source was first detected in hard X–rays above 20 keV with *INTEGRAL*, in the 2nd IBIS survey (Bird et al. 2006; see also the 3rd IBIS survey of Bird et al. 2007) and in the IBIS extragalactic survey of Bassani et al. (2006), at a 20–100 keV flux of $\sim 3 \times 10^{-11}$ erg cm $^{-2}$ s $^{-1}$, assuming a Crab-like spectrum. Through positional cross-correlation analysis, Stephen et al. (2006) associated this emission with the *ROSAT* source 1RXS J161933.6–280736 (Voges et al. 1999), which has a flux of 1.1×10^{-11} erg cm $^{-2}$ s $^{-1}$ in the 0.1–2.4 keV band, again assuming a Crab-like spectrum. On statistical grounds, Stephen et al. (2006) pointed out that this source is most likely the soft X–ray counterpart of IGR J16194–2810.

The 8''-radius *ROSAT* X–ray error box encompasses 3 relatively bright optical objects (see Fig. 1). In order to better study this source in the soft X–ray band, and to reduce its error circle to pinpoint its optical counterpart, we performed observations with the X–Ray Telescope (XRT, 0.3–10 keV; Burrows et al. 2006) on board *Swift* (Gehrels et al. 2004). These observations were part of our program of follow-up pointings of *INTEGRAL* sources at soft X–rays with *Swift*/XRT.

The capabilities of XRT allow the position of an X–ray source to be determined with an uncertainty which can be better than 4'', and can secure a nominal spectral coverage between 0.3 and 10 keV. We also collected hard X–ray archival data of IGR J16194–2810 with the IBIS instrument (Ubertini et al. 2003) on board *INTEGRAL* (Winkler et al. 2003). In parallel, we performed optical spectroscopic observations of the field of this source at the South African Astronomical Observatory (SAAO).

The paper is structured as follows: Sect. 2 and 3 will present X–ray and optical observations of IGR J16194–2810, respectively; in Sect. 4 the results of this multiwavelength campaign will be given, and in Sect. 5 a discussion on them will be presented. Finally, Sect. 6 will draw the conclusions and will outline possible future work

Table 1. Log of the *Swift*/XRT observations used in this paper.

Observation number	Start day	Start time (UT)	On-source time (ks)
1	29 Jan 2007	03:36:10	5.2
2	01 Feb 2007	18:21:24	2.6

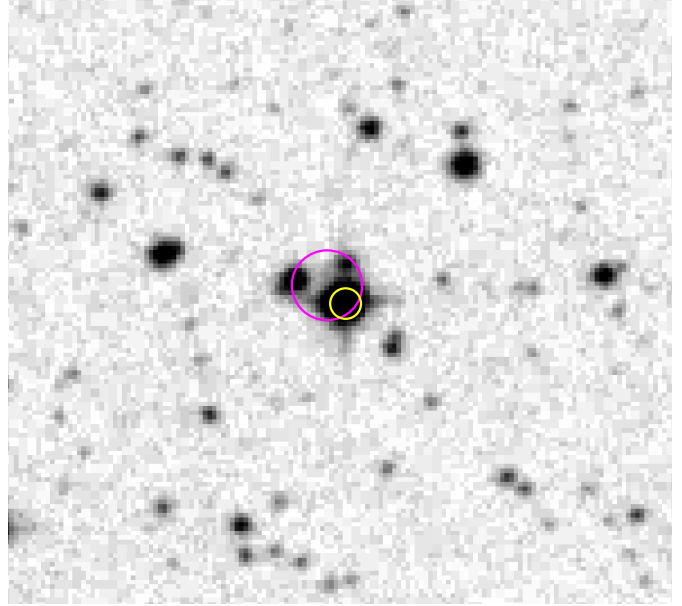


Fig. 1. DSS-II-Red image of the field of IGR J16194–2810 with the 0.3–10 keV band *Swift*/XRT (smaller circle) and the 0.1–2.4 *ROSAT*/PSPC (larger circle) X–ray positions superimposed. The only star positionally consistent with the XRT error circle is the brighter one at the centre of the image, the M-type giant USNO-A2.0 U0600_20227091. In the figure, North is at top and East is to the left. The field size is $\sim 2'.5 \times 2'.5$.

on this source. Throughout the paper, uncertainties are given at a 90% confidence level.

2. X–ray observations

We observed the field of IGR J16194–2810 with XRT onboard *Swift* twice; both pointings were performed in Photon Counting mode (see Burrows et al. 2006 for details on this observing mode). The log of these observations is reported in Table 1.

The data reduction was performed using the XRTDAS v2.0.1 standard data pipeline package (`xrtpipeline` v0.10.6) in order to produce the final cleaned event files. As in both observations the XRT count rate of the source was high enough to produce data pile-up, we extracted the events in an annulus centered on the source and 47'' wide. The size of the inner circle was determined following the procedure described in Romano et al. (2006) and was 7'' for the first observation and 4''.7 for the second one.

The source background was measured within a circle with radius $95''$ located far from the source. The ancillary response file was generated with the task `xrtmkarf` (v0.5.2) within `FTOOLS`¹ (Blackburn 1995), and accounts for both extraction region and PSF pile-up correction. We used the latest spectral redistribution matrices in the Calibration Database² (CALDB 2.3) maintained by HEASARC.

We also extracted the spectral and time-series data of this source collected with the coded-mask ISGRI detector (Lebrun et al. 2003) of the IBIS instrument on-board *INTEGRAL*. ISGRI data were processed using the standard *INTEGRAL* analysis software (OSA³ v5.1; Goldwurm et al. 2003); events in the band 17–300 keV, coming from both fully-coded and partially-coded observations of the field of view of IGR J16194–2810, were considered in the analysis. The time resolution for these data was that typical of IBIS science windows (~ 2 ks). Details on the whole procedure can be found in Bird et al. (2007). Hard X–ray long-term light curves and a time-averaged spectrum were then obtained from the available data and using the method described in Bird et al. (2006, 2007), for a total of 461 ks on-source collected in the time interval October 2002 - April 2006.

3. Optical observations

One medium-resolution optical spectrum of the star in the *Swift*/XRT error box (see Fig. 1 and Sect. 4) was acquired starting at 19:00 UT of 22 July 2005 with the 1.9-metre “Radcliffe” telescope located near Sutherland, South Africa. The exposure time was 300 s. This telescope carries a spectrograph mounted at the Cassegrain focus; the instrument was equipped with a 1798×266 pixel SiTe CCD. Grating #7 and a slit of $1''.8$ were used, providing a 3850–7200 Å nominal spectral coverage. This setup gave a dispersion of 2.3 Å/pix.

The spectrum, after correction for flat-field, bias and cosmic-ray rejection, was background subtracted and optimally extracted (Horne 1986) using IRAF⁴. Wavelength calibration was performed using Cu–Ar lamps, while flux calibration was accomplished by using the spectrophotometric standards CD –32°9927 and LTT 377 (Hamuy et al. 1992, 1994). Wavelength calibration uncertainty was ~ 0.5 Å; this was checked by using the positions of background night sky lines.

4. Results

Only one X–ray source was found in both XRT observations within the $3'.5$ IBIS error box of IGR J16194–2810 (Bird et al. 2007). Using the data of XRT obs. 1 (i.e., the deeper one), we determined the position of IGR J16194–2810 using the `xrtcentroid` (v0.2.7) task. The correction for the misalignment between the telescope and the satellite optical axis was taken into account (see Moretti et al. 2006 for details). The coordinates we obtained for the source are the following (J2000): RA = $16^{\text{h}} 19^{\text{m}} 33^{\text{s}}.29$; Dec = $-28^{\circ} 07' 40''.8$ (with a 90% confidence level error of $3''.5$ on both coordinates). This position is fully consistent with the *ROSAT* one (see Fig. 1); thus, we can confidently say that these three X–ray objects (the *INTEGRAL*, the *ROSAT* and the *Swift* ones) are the same.

Only the brightest of the optical sources within the *ROSAT* error box, object USNO-A2.0 U0600_20227091, at coordinates (J2000) RA = $16^{\text{h}} 19^{\text{m}} 33^{\text{s}}.363$; Dec = $-28^{\circ} 07' 39''.02$ (with an error of $0''.2$ on both coordinates: Deutsch 1999; Assafin et al. 2001), is contained in the XRT uncertainty circle, at $2''$ from the XRT centroid.

The inspection of the optical spectrum of this object (reported in Fig. 2) clearly shows the typical features of a M-type star (Jaschek & Jaschek 1987): it is dominated by TiO absorption bands and no emission features typical of X–ray binaries, such as Balmer and He II lines, are readily apparent. We also find, among the main spectral features, the Mg absorption band around 5170 Å, the Ca I line at 4226 Å and two atomic line blends of metal intersystem lines of Fe I, Ti I, Cr I, Ba I, Ca I, Mn I, Co I and Ni I located at 6352 Å and 6497 Å (see e.g. Turnshek et al. 1985). A telluric absorption feature is moreover detected at 6870 Å. A narrow H α line is detected in absorption, although with possible wider emission wings (see inset in Fig. 2), similarly to what found by Gaudenzi & Polcaro (1999) in the optical spectrum of 4U 1700+24. However, given that the same profile is seen in the telluric feature at 6870 Å, we believe that this is more due to an effect produced by the stellar continuum shape, rather than to the actual presence of emission wings around the H α absorption.

Using the Bruzual-Persson-Gunn-Stryker⁵ (Gunn & Stryker 1983) and Jacoby-Hunter-Christian⁶ (Jacoby et al. 1984) spectroscopy atlases, we then compared the spectrum of star U0600_20227091 with those of several late-type stars. The best match is obtained with star BD –02°4025 (of type M2 III), with no substantial intervening interstellar absorption. Thus, we classify U0600_20227091 as a star of spectral type M2 III.

¹ available at:

<http://heasarc.gsfc.nasa.gov/ftools/>

² available at: <http://heasarc.gsfc.nasa.gov/docs/heasarc/caldb/caldb-intro.html>

³ available at:

<http://isdc.unige.ch/index.cgi?Soft+download>

⁴ IRAF is the Image Analysis and Reduction Facility made available to the astronomical community by the National Optical Astronomy Observatories, which are operated by AURA, Inc., under contract with the U.S. National Science Foundation. It is available at <http://iraf.noao.edu/>

⁵ available at:

<ftp://ftp.stsci.edu/cdbs/cdbs1/grid/bpgs/>

⁶ available at:

<ftp://ftp.stsci.edu/cdbs/cdbs1/grid/jacobi/>

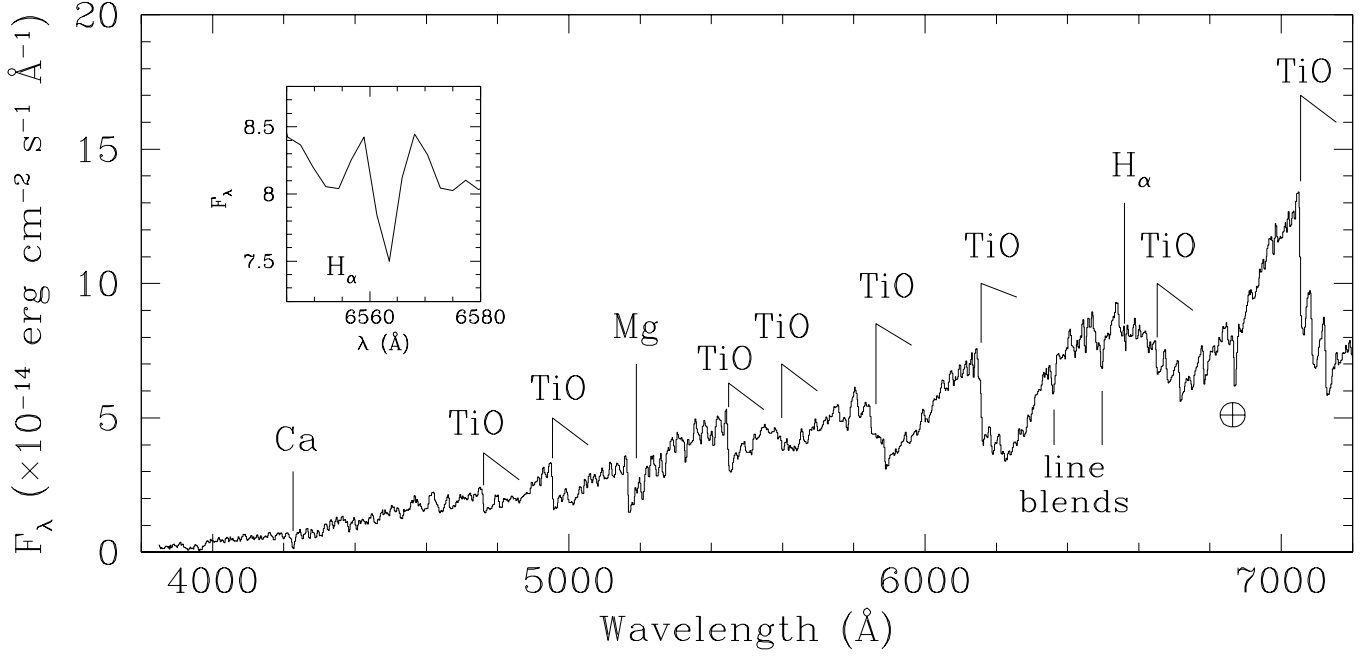


Fig. 2. 3850–7200 Å optical spectrum of the counterpart of IGR J16194–2810 obtained with the SAAO 1.9-meter Radcliffe telescope on 22 July 2005. The spectrum is typical of a star of type M2 III (see text). The telluric absorption bands are marked with the symbol \oplus . The inset shows a close-up of the spectrum around the H_α region.

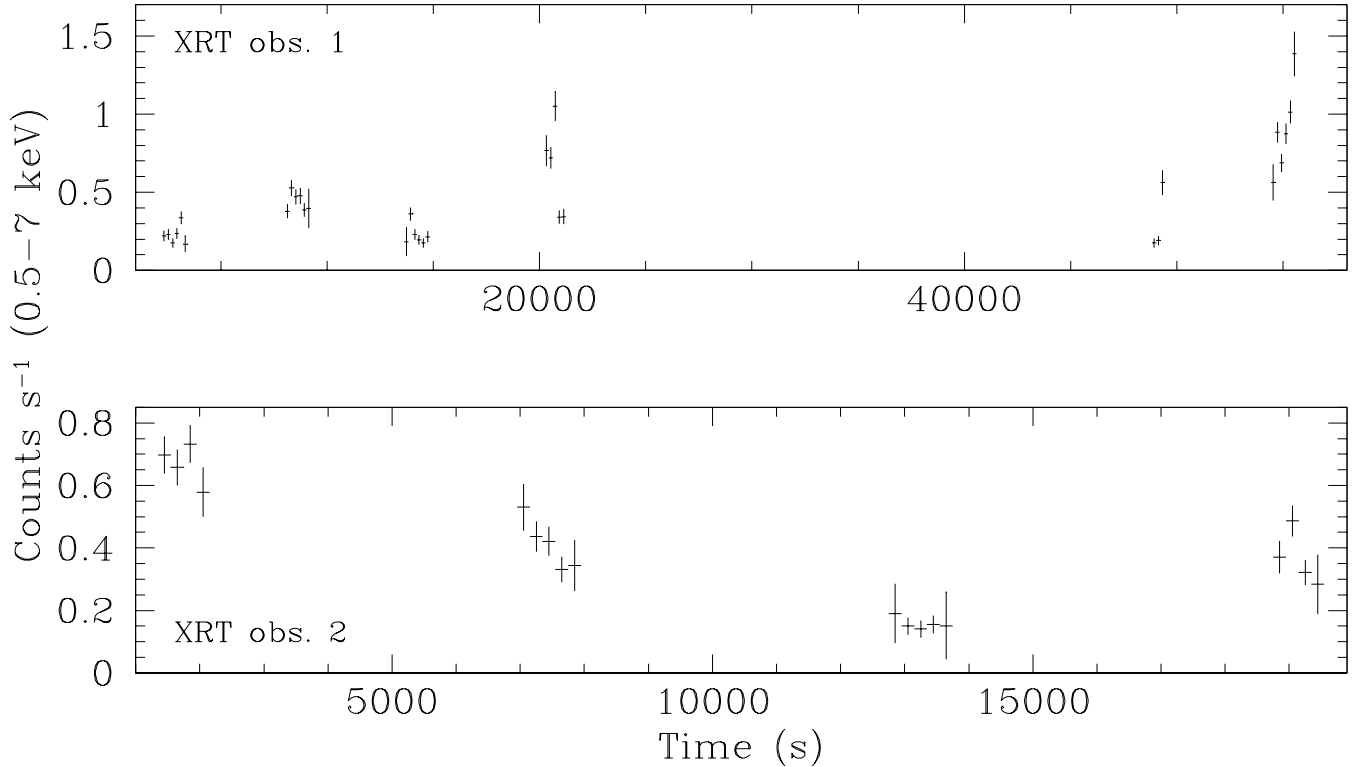


Fig. 3. 0.5–7 keV X-ray light curves, binned at 200 s, of IGR J16194–2810 as seen during the XRT pointed observations reported in the text. Times are in seconds since the beginning of the observation as reported in Table 1.

Next, from the R -band magnitude ($R \sim 11.0$) extracted from the USNO-A2.0 catalogue⁷ and from the $V - R$ color index of a M2 III star (1.27; Ducati et al. 2001), we determine $V \sim 12.3$ for the counterpart of IGR J16194–2810. Assuming that a star of this spectral type has an absolute magnitude $M_V = -0.6$ (Lang 1992), we obtain a distance $d \sim 3.7$ kpc. We stress that this should conservatively be considered as an upper limit to the distance to this object, as the effect of any amount of interstellar absorption along the line of sight was not accounted for. This correction, however, should not be substantial as the optical spectrum of the source shows no evidence of reddening, as mentioned before.

The light curves of the pointed XRT observations (Fig. 3) extracted in the 0.5–7 keV band, in which the two pointings allowed us to collect sufficient statistics from IGR J16194–2810, show erratic fluctuations of the source emission on variability timescales from hundreds to thousands of seconds. This is typical of accreting Galactic sources in general and of SyXBs in particular (see Masetti et al. 2002, 2006b). The hardness ratio between the 3–7 keV and 0.5–3 keV energy bands did not change significantly in each of the two single XRT observations, as well as between them.

Timing analysis on the XRT 0.5–7 keV data was performed with the task `powspec` within the FTOOLS package, after having converted the event arrival times to the Solar System barycentric frame and having considered the two *Swift* pointing together, so to increase the available statistics. We constructed the corresponding Power Spectral Density (PSD) using a time resolution of 5 s and dividing the XRT light curve in 258 intervals, each one made of 256 bins of 5 s duration. The PSD thus obtained, in the time frequency interval $f \sim 10^{-4} - 0.1$ Hz, is characterized by red noise with a $1/f$ trend. This is typical of sources showing shot-noise variability in their X-ray light curve.

Using the Lomb-Scargle method as described in Sguera et al. (2007), we then investigated the 20–100 keV long-term ISGRI light curve of IGR J16194–2810 to search for periodicities on days to months timescales, possibly connected with the orbital period of the system, as in the case of 4U 1700+24 (which displays a periodicity of ≈ 400 days: Masetti et al. 2002; Galloway et al. 2002). No indication of any periodic modulation was found in the range between 1 and ~ 400 days. A similar investigation was performed in narrower spectral ranges (17–30, 20–40 and 18–60 keV) to search for periodic signals limited to these bands, but an identical null result was obtained.

X-ray spectral analysis was performed with the package XSPEC (Arnaud 1996) v11.3.2. The time-averaged spectra were rebinned to have a minimum of 20 counts per bin, such that the χ^2 statistics could reliably be used. As no significant variations in the X-ray hardness of the source were found during both *Swift* observations, we decided to consider the 0.5–7 keV XRT spectrum averaged

Table 2. Best-fit parameters of the Comptonization model adopted to describe the 0.5–200 keV X-ray spectrum of IGR J16194-2810 presented in this paper. As quoted in the text, uncertainties are given at a 90% confidence level. The reported fluxes are in $\text{erg cm}^{-2} \text{s}^{-1}$ and are corrected for the intervening absorption column as determined from the spectral fitting. The 0.5–200 keV luminosity, expressed in erg s^{-1} , is computed assuming a distance $d = 3.7$ kpc to IGR J16194-2810.

Parameter	Value
χ^2/dof	133/146
N_{H} (10^{22} cm^{-2})	$0.16^{+0.08}_{-0.07}$
kT_0 (keV)	$0.63^{+0.08}_{-0.07}$
kT_e (keV)	$7.6^{+6.8}_{-1.6}$
τ	$6.8^{+2.3}_{-3.2}$
K_{Comp}	$(1.7^{+0.6}_{-0.9}) \times 10^{-3}$
$F_{(0.5-2 \text{ keV})}$	7.7×10^{-12}
$F_{(2-10 \text{ keV})}$	4.4×10^{-11}
$F_{(20-100 \text{ keV})}$	1.6×10^{-11}
$F_{(0.5-200 \text{ keV})}$	8.8×10^{-11}
$L_{(0.5-200 \text{ keV})}$	1.4×10^{35}

over the two pointings. We also accumulated a 18–200 keV ISGRI spectrum averaged over the entire on-source time spent by *INTEGRAL* on IGR J16194–2810. A normalization factor between the XRT and the ISGRI spectra was introduced to take the non-simultaneity of the observations into account.

We first attempted a fit of the X-ray spectrum with a simple absorbed power law, returning a photon index $\Gamma = 1.66^{+0.12}_{-0.11}$. However, the obtained χ^2 is 221 for 152 degrees of freedom (dof). This fact and the examination of the fit residuals suggest that a high-energy spectral break is present and that a more detailed model is needed to describe the X-ray spectrum of the source.

Next, following our past experience on SyXBs (Masetti et al. 2002, 2006b), we fit the averaged spectrum of the source with a more physical model composed of a thermal Comptonization (Titarchuk 1994) attenuated by a neutral hydrogen column. With this model we obtained a satisfactory description of the spectrum, as reported in Table 2 and in Fig. 4, in the assumption of a spherical distribution of the Comptonization plasma around the accreting compact object. According to the F -test statistics (e.g., Bevington 1969), the chance improvement probability of this model over the simple power-law description is 2×10^{-3} , indicating the better statistical quality of the Comptonization model for the X-ray spectrum of IGR J16194–2810.

The use of a disk geometry for the Comptonization plasma gives parameter values which are consistent within errors with those obtained assuming a spherical distribution but τ , which in this case is $3.2^{+1.1}_{-1.8}$ and therefore only

⁷ available at:

<http://archive.eso.org/skycat/servers/usnoa/>

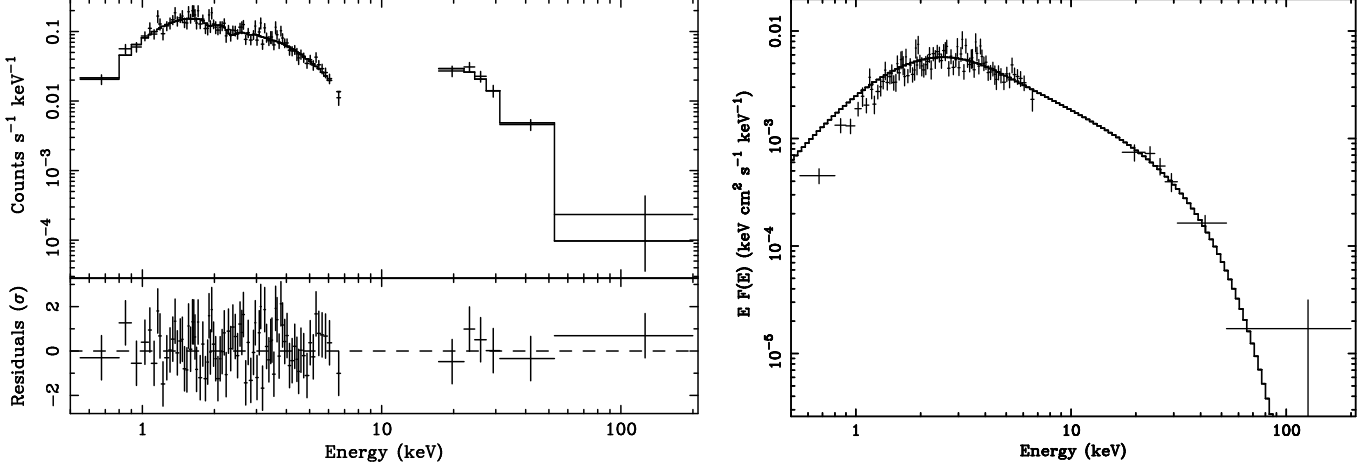


Fig. 4. *Left:* averaged 0.5–200 keV X-ray spectrum of IGR J16194–2810 obtained from the XRT and ISGRI data described in the text. The fit residuals using the best-fit model reported in Table 2 are also shown. *Right:* deconvolved, absorption-corrected $E \times F(E)$ best-fit model of the X-ray spectrum (continuous line histogram) overplotted on the actual X-ray spectral data of the source.

marginally compatible with the value of this parameter in the spherical case. However (see also next Section), due to the fact that the accretion flow in this system is likely stemming from the stellar wind of the secondary (which carries little angular momentum), it is fair to assume that the accretion geometry has a spherical form.

It was also found that the XRT/ISGRI intercalibration factor is of order unity (~ 1.5), indicating that the source did not undergo severe changes in the intensity between the *INTEGRAL* and the *Swift* observations.

No iron emission was found in the spectrum: assuming a Fe line with energy 6.7 keV and a width of 0.1 keV, the 90% upper limit on its equivalent width is 82.5 eV. This result is compatible with those from other SyXBs (Masetti et al. 2002, 2006b).

5. Discussion

The X-ray spectral evidence, as well as the X-ray light curve behaviour of IGR J16194–2810 strongly suggests that this source is a Galactic X-ray binary. Furthermore, the positional coincidence of this X-ray source with a M-type giant, as a matter of facts, indicates that the two objects are likely the same and that IGR J16194–2810 is a SyXB. For the sake of comparison, and for the reader’s use, we collect in Table 3 the main properties of the 5 SyXBs known up to now, thus extending Table 2 of Galloway et al. (2002) with the new results on the sources belonging to this subclass of LMXBs.

Following Kaplan et al. (2007), one can use the 2MASS *K*-band near-infrared magnitude of star U0600_20227091 (Skrutskie et al. 2006) to evaluate the chance coincidence probability of finding a bright red giant within the XRT error box. This star has a magnitude $K = 6.98$; in this area of the sky, and the number of stars brighter than $K = 7$ mag is ~ 15 per square degree. This means that the chance probability of finding such a bright star within the

XRT error circle is $\sim 4 \times 10^{-5}$. Therefore, the low random chance of a positional coincidence of this X-ray source with a M-type giant further strongly supports the physical association of these two objects.

Thus, we can confidently state that U0600_20227091 is indeed the actual optical counterpart of IGR J16194–2810, and that this X-ray object is indeed a SyXB located at $\lesssim 3.7$ kpc from Earth. This distance is similar to that suggested by Kaplan et al. (2007) for the SyXB Sct X-1. It also means that the 2–10 keV band luminosity of this source is $\lesssim 7.2 \times 10^{34}$ erg s $^{-1}$, which is similar to that of other objects of this subclass (e.g., Masetti et al. 2002, 2006a,b; see also Table 3). If we compare the 2–10 keV X-ray luminosity of the system with the total luminosity of its M-type giant companion, $\sim 550 L_{\odot}$ (Lang 1992), i.e. 2×10^{36} erg s $^{-1}$ (most of which is emitted in the optical and near-infrared bands) we see that, as for nearly all other SyXBs, the optical light due to the reprocessing of X-ray irradiation is overwhelmed by the emission of the M-type giant star.

We note that the absence of apparent interstellar absorption in the optical spectrum is at odds with the N_{H} obtained from our X-ray spectral fitting (see Table 2), which implies $A_V \sim 1$ mag, according to the empirical formula of Predehl & Schmitt (1995). This suggests that most of this hydrogen column, likely connected with the accretion stream, is concentrated around the compact object. This is not uncommon in SyXBs (see e.g. Masetti et al. 2006b).

The PSD obtained from the XRT data has the characteristics of the $1/f$ -type shot-noise variability often seen in this class of objects (e.g., Masetti et al. 2002, 2006b) and likely due to random instabilities in the accretion process, or to inhomogeneities in the accreting stellar wind captured by a NS (see e.g. Kaper et al. 1993). Thus, a straightforward explanation for the X-ray activity from this source is that it is produced by inhomogeneities in

Table 3. Synoptic table containing the main parameters of the 5 SyXBs known. The X–ray luminosity L_X considered in the table refers to the 2–10 keV band. For the computation of the $L_X/L_{\text{secondary}}$ ratios, bolometric luminosities of the secondary stars are taken from Lang (1992). The mass accretion rate \dot{M} was computed assuming an accreting NS with radius $R_{\text{NS}} = 10$ km and mass $M_{\text{NS}} = 1.4 M_{\odot}$.

Parameter	GX 1+4	4U 1700+24	4U 1954+31	Sct X-1	IGR J16194–2810
Spectral type of the secondary	M5 III [1]	M2 III [2]	M4-5 III [3]	M0 I ? [4]	M2 III [5]
V-band magnitude	18.4 [1]	7.7 [6]	10.7 [3]	6.6 (K_s) [4]	12.3 [5]
A_V (mag)	5.0 [1]	≈ 0 [2]	≈ 0 [3]	≈ 24 [4]	≈ 0 [5]
Distance (kpc)	3–6 [1]	0.42 [2]	$\lesssim 1.7$ [3]	≈ 4 ? [4]	$\lesssim 3.7$ [5]
X–ray spectrum	[7]	[2,8]	[9]	[4,10]	[5]
L_X (erg s $^{-1}$)	$\sim 10^{37}$ [1]	$2 \times 10^{32} - 10^{34}$ [2]	$4 \times 10^{32} - 10^{35}$ [3,9]	$\approx 2 \times 10^{34}$? [4]	$\lesssim 7 \times 10^{34}$ [5]
$L_X/L_{\text{secondary}}$	~ 2.9	$10^{-4} - 5 \times 10^{-3}$	$1.1 \times 10^{-4} - 3 \times 10^{-2}$	1.3×10^{-4} ?	$\lesssim 3.3 \times 10^{-2}$
\dot{M} (g s $^{-1}$)	5.4×10^{16}	$1.1 \times 10^{12} - 5.4 \times 10^{13}$	$2.2 \times 10^{12} - 1.1 \times 10^{15}$	$\approx 1.1 \times 10^{14}$?	$\lesssim 3.8 \times 10^{14}$
P_{spin} (s)	~ 140 [7]	—	~ 18300 [11]	113 [4]	—
$\dot{P}_{\text{spin}}/P_{\text{spin}}$ (s $^{-1}$)	variable [7, 12]	—	-1.4×10^{-9} [11]	3.9×10^{-9} [4]	—
P_{orb} (d)	304 [13, 14]	404 [2,15]	—	—	—

References: [1] Chakrabarty & Roche (1997); [2] Masetti et al. (2002); [3] Masetti et al. (2006a); [4] Kaplan et al. (2007); [5] this work; [6] Tomasella et al. (1997); [7] Ferrigno et al. (2007); [8] Tiengo et al. (2005); [9] Masetti et al. (2006b); [10] Cooke et al. (1984); [11] Corbet et al. (2006); [12] Nagase (1989); [13] Cutler et al. (1986); [14] Pereira et al. (1999); [15] Galloway et al. (2002).

the accretion flow onto a compact object, possibly a NS (e.g. van der Klis 1995).

Although no short-term periodicity linked to the spin of the accreting object has been found in the XRT data analysis, it may be likely that, if the accretor is a NS, this spin period is $\lesssim 100$ s. Indeed (see also Table 3), we note that slowly rotating pulsars appear to be usual in SyXBs, as the NSs hosted in these systems display spin periodicities ranging from hundreds of seconds (Lewin et al. 1971; Kaplan et al. 2007) to hours (Corbet et al. 2006, 2007). Thus, any theory aiming at an accurate description of the evolution of this kind of LMXB should also explain this peculiarity.

The best-fit X–ray spectral model is also typical of X–ray binary systems hosting a NS accreting from a stellar wind (e.g., Masetti et al. 2004, 2006c). We should note that the presence of a black hole (BH), rather than a NS, in this system cannot however be excluded; nevertheless, the temperatures associated with the Comptonization component are those generally seen in LMXBs hosting an accreting NS (e.g., Paizis et al. 2006).

A possible further indication that the accreting matter is flowing onto the polar caps of a NS via magnetic field

confinement comes from the estimate of the size r_0 of the region emitting the Comptonization soft X–ray seed photons. Following the prescription by in 't Zand et al. (1999) for the computation of r_0 , and using the best-fit spectral parameters reported in Table 2 in the assumption of a spherical plasma cloud, we obtain that $r_0 \sim 1.4$ km. This estimate suggests that the area emitting soft seed photons on the NS covers only a fraction of its surface and it is comparable with the size of the base of an accretion column, which is ≈ 0.1 times the NS radius (e.g., Hickox et al. 2004).

The fact that, assuming that an accreting NS is harboured in this system, IGR J16194–2810 does not show X–ray pulsations, at variance with GX 1+4 or Sct X-1, may be due to geometric effects (such as a low inclination of the system and/or the quasi-alignment between the rotation and the magnetic field axes), as invoked by Masetti et al. (2002, 2006b) for 4U 1700+24 and 4U 1954+31. Alternatively, the plasma cloud surrounding the NS may completely comptonize the soft X–ray emission coming from it and therefore may smear out any periodic modulation emitted by the NS surface (e.g., Titarchuk et al. 2002); indeed, this latter interpretation is supported by

the fact that we do not see any direct thermal radiation from the NS in the X–ray spectrum. Of course, we cannot exclude that a combination of the two effects above is at work in IGR J16194–2810.

We thus suggest that IGR J16194–2810 is a SyXB with overall characteristics which are broadly similar to those of systems 4U 1700+24 and 4U 1954+31, in which a compact object, likely a NS, moves around a M-type giant in a wide orbit and accretes from its stellar wind (Masetti et al. 2002, 2006b).

6. Conclusions

Using multiwavelength information extending from optical wavelengths to the hard X–ray range we characterized the nature of source IGR J16194–2810 and found that it is a SyXB possibly hosting a (slowly rotating?) NS accreting from the wind of its M-type giant companion. This is the fifth object belonging to this small but growing class of peculiar Galactic X–ray binaries.

Future optical spectrophotometry studies on this object may shed light on the determination of its orbital period; likewise, the study of its long-term X–ray behaviour using monitoring instruments at energies below 20 keV can help in the determination of any long-term periodicity. In parallel, pointed observation with X–ray satellites with high spectral (e.g., *XMM-Newton* or *Chandra*) and temporal (*RXTE*) sensitivity can explore the nature of the detected X–ray emission and can search for the presence of any pulsed signal or of other short timescale periodicities in the X–ray light curve of this object, for a full characterization of this rare source.

Acknowledgements. We thank Giancarlo Cusumano for useful advices concerning the XRT data reduction and analysis, and Mauro Orlandini, Loredana Bassani and Eliana Palazzi for several important remarks and suggestions. We also thank the anonymous referee for useful comments which helped us to improve the quality of this paper. This research has made use of the NASA’s Astrophysics Data System, of the 2MASS survey, of the HEASARC archive, and of the SIMBAD database operated at CDS, Strasbourg, France. The authors acknowledge the ASI and INAF financial support via grant No. 1/023/05/0.

References

- Arnaud, K.A. 1996, XSPEC: the first ten years, in *Astronomical Data Analysis Software and Systems V*, ed. G.H. Jacoby, & J. Barnes, ASP Conf. Ser., 101, 17
- Assafin, M., Andrei, A.H., Vieira Martins, R., et al. 2001, *ApJ*, 552, 380
- Bassani, L., Molina, M., Malizia, A., et al. 2006, *ApJ*, 636, L65
- Bird, A.J., Barlow, E.J., Bassani, L., et al. 2006, *ApJ*, 636, 765
- Bird, A.J., Malizia, A., Bazzano, A. et al. 2007, *ApJS*, 170, 175
- Bevington, P.R. 1969, *Data reduction and error analysis for the physical sciences* (New York: McGraw-Hill Book Company)
- Blackburn, J.K. 1995, FTOOLS: A FITS Data Processing and Analysis Software Package, in *Astronomical Data Analysis Software and Systems IV*, ed. R.A. Shaw, H.E. Payne, & J.J.E. Hayes, ASP Conf. Ser., 77, 367
- Burrows, D.N., Hill, J.E., Nousek, J.A., et al. 2005, *Space Sci. Rev.*, 120, 165
- Chakrabarty, D., & Roche, P. 1997, *ApJ*, 489, 254
- Cooke, B.A., Levine, A.M., Lang, F.L., Primini, F.A., & Lewin, W.H.G. 1984, *ApJ*, 285, 258
- Corbet, R.H.D., Barbier, L., Barthelmy, S. et al. 2006, *ATel* 797
- Corbet, R.H.D., Markwardt, C.B., Barbier, L., et al. 2007, *Progr. Theor. Phys. Suppl.*, in press [[astro-ph/0703274](#)]
- Cutler, E.P., Dennis, B.R., & Dolan, J.F. 1986, *ApJ*, 300, 551
- Davidson, A., Malina, R., & Bowyer, S. 1977, *ApJ*, 211, 866
- Deutsch, E.W. 1999, *AJ*, 118, 1882
- Ducati, J.R., Bevilacqua, C.M., Rembold, S.B., & Ribeiro, D. 2001, *ApJ*, 558, 309
- Ferrigno, C., Segreto, A., Santangelo, A., et al. 2007, *A&A*, 462, 995
- Galloway, D., Sokoloski, J.L., & Kenyon, S.J. 2002, *ApJ*, 580, 1065
- Garcia, M.R., Baliunas, S.L., Doxsey, R., et al. 1983, *ApJ*, 267, 291
- Gaudenzi, S., & Polcaro, V.F. 1999, *A&A*, 347, 473
- Gehrels, N., Chincarini, G., Giommi, P., et al. 2004, *ApJ*, 611, 1005
- Goldwurm, A., David, P., Foschini, L., et al. 2003, *A&A*, 411, L223
- Gunn, J.E., & Stryker, L.L. 1983, *ApJS*, 52, 121
- Hamuy, M., Walker, A.R., Suntzeff, N.B., et al. 1992, *PASP*, 104, 533
- Hamuy, M., Suntzeff, N.B., Heathcote, S.R., et al. 1994, *PASP*, 106, 566
- Hickox, R.C., Narayan, R., & Kallman, T.R. 2004, *ApJ*, 614, 881
- Horne, K. 1986, *PASP*, 98, 609
- in ’t Zand, J.J.M., Verbunt, F., Strohmayer, T.E., et al. 1999, *A&A*, 345, 100
- Jacoby, G.H., Hunter, D.A., & Christian, C.A. 1984, *ApJS*, 56, 257
- Jaschek, C., & Jaschek, M. 1987, *The Classification of Stars* (Cambridge: Cambridge Univ. Press)
- Kaper, L., Hammerschlag-Hensberge, G., & van Loon, J.T. 1993, *A&A*, 279, 485
- Kaplan, D.L., Levine, A.M., Chakrabarty, D., et al. 2007, *ApJ*, 661, 437
- Koyama, K., Kunieda, H., Takeuchi, Y., & Tawara Y. 1991, *ApJ*, 370, L77
- Lang, K.R. 1992, *Astrophysical Data: Planets and Stars*. Springer-Verlag, New York
- Liu, Q.Z., van Paradijs, J., & van den Heuvel, E.P.J. 2001, *A&A*, 368, 1021
- Leahy, D.A., Darbro, W., Elsner, R.F., et al. 1983, *ApJ*, 266, 160
- Lebrun, F., Leray, J.P., Lavocat, P., et al. 2003, *A&A*, 411, L141
- Lewin, W.H.G., Ricker, G.R., & McClintock, J.E. 1971, 169, L17
- Masetti, N., Dal Fiume, D., Cusumano, G., et al. 2002, *A&A*, 382, 104
- Masetti, N., Dal Fiume, D., Amati, L., et al. 2004, *A&A*, 423, 311
- Masetti, N., Orlandini, M., Palazzi, E., Amati, L., & Frontera, F. 2006a, *A&A*, 453, 295
- Masetti, N., Rigon, E., Maiorano, E., et al. 2006b, *A&A*, 464, 277

- Masetti, N., Orlandini, M., Dal Fiume, D., et al. 2006c, *A&A*, 445, 653
- Mattana, F., Götz, D., Falanga, M., et al. 2006, *A&A*, 460, L1
- Moretti, A., Perri, M., Capalbi, M., et al. 2006, *A&A*, 448, L9
- Nagase, F. 1989, *PASJ*, 41, 1
- Paizis, A., Farinelli, R., Titarchuk, L. et al. 2006, *A&A*, 459, 187
- Pereira, M.G., Braga, J., & Jablonski, F. 1999, *ApJ*, 526, L105
- Predehl, P., & Schmitt, J.H.M.M. 1995, *A&A*, 293, 889
- Romano, P., Campana, S., Chincarini, G., et al. 2006, *A&A*, 456, 917
- Skrutskie, M.F., Cutri, R.M., Stiening, R., et al. 2006, *AJ*, 131, 1163
- Sguera, V., Hill, A.B., Bird, A.J., et al. 2007, *A&A*, 467, 249
- Stephen, J.B., Bassani, L., Malizia, A., et al. 2006, *A&A*, 445, 869
- Tiengo, A., Galloway, D.K., Di Salvo, T., et al. 2005, *A&A*, 441, 283
- Titarchuk, L. 1994, *ApJ*, 434, 570
- Titarchuk, L., Cui, W., & Wood K. 2002, *ApJ*, 576, L49
- Tomasella, L., Munari, U., Tomov, T., et al. 1997, *IBVS* 4537
- Turnshek, D.E., Turnshek, D.A., Craine, E.C., & Boeshaar, P.C. 1985, *An atlas of digital spectra of cool stars*. Western Research Company, Tucson
- Ubertini, P., Lebrun, F., Di Cocco, G., et al. 2003, *A&A*, 411, L131
- van der Klis, M. 1995, Rapid aperiodic variability in X-ray binaries, in *X-ray Binaries*, ed. W.H.G. Lewin, J. van Paradijs & E.P.J. van den Heuvel (Cambridge: Cambridge Univ. Press), 252
- Voges, W., Aschenbach, B., Boller, T., et al. 1999, *A&A*, 349, 389
- Winkler, C., Courvoisier, T.J.-L., Di Cocco, G., et al. 2003, *A&A*, 411, L1